

A semantic data model for electrical discharge machining

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Abstract

Machining condition data are used as an input of a CNC machine tool. In general for a given set of machining requirements, human experts decide machining conditions based on their knowledge and experience. To construct machining databases, which are reusable and sharable their structures and meanings, semantic data model is required. In this study a semantic data model required for construction of electrical discharge machining (EDM) databases is developed. It combines conventional data models with ISO/IEC 11179 standard, metadata registry (MDR). Names of object classes and properties constituting data element names are identified using conventional data model while data elements are named and specified based on ISO/IEC 11179 in order to obtain semantic interoperability of data. An experimental application to EDM is performed to explain the semantic data modeling process.

Keywords: Data semantics, Data models, Metadata, Electrical discharge machining

1. Introduction

A database is more than just a collection of values. It is a model of a real world system. Therefore, the data model should mirror the structure of the system that it models in order to build a good database. Till now most data models were representational models rather than semantic models [1]. However, semantic data models will be getting more important as time passed.

Conventional data models are too low level to allow the meaning of a database to be directly expressed. To obtain semantic interoperability between databases analysing the structure of data elements will be helpful. ISO/IEC 11179 standard, metadata registry, is dealing the structure of data elements so that could help conventional data models to have semantic modelling function.

ISO/IEC 11179 makes databases to share meanings and specifications by maintaining

standardized metadata through registering and verifying [2]. However the standard provides only the principles of metadata management. The implementation of the standard should be done in detail in every domain according to the principles the standard provides.

In a machining system it is very important to acquire optimal machining conditions which are able to be used in machining products of a lot of materials and features [3]. Databases accumulating verified experiential data can be utilized in finding optimal machining conditions. These data will be exchanged between machining systems. In that case the interoperability of data will be raised up.

In this paper a semantic data model is developed and the model is used for developing a data model to construct a knowledge base, which support the selection of machining conditions of EDM.

2. Related work

Distributed agent architecture was developed to address the need for semantic interoperability of environmental data in the InfoSleuth project [4], which provides for semantic interchange among users by allowing an application developer to express the concepts and relationships of application domain in high-level terms that are then translated into the low-level types of database schemas. Jeong et al [5] suggested a couple of rules to solve the inconsistency of value representation and developed a protocol, Metadata Semantics Description Language (MSDL), based on XML. These two studies are dealing with semantic interoperability of data without any consideration for data modelling at all.

Setchi et al [6] suggested a semantic modelling methodology not only to be able to reuse but also to increase the interoperability of data in the product support system using ontological way. They broke down product support knowledge into three categories such as product knowledge, user knowledge, and task knowledge and then performed a two step modelling including architectural model and functional model. Pham et al [7] proposed a semantic data model for product support systems (PSS) based on an information usage analysis. They classified information with regard to its usage from three different perspectives: the intended purpose for the product information, the supported user tasks, and the functional characteristics of the product information elements. Lee et al [8] proposed a knowledge framework made up of three levels of knowledge including domain specific knowledge, a knowledge map, and axioms; the axioms specify the semantics of concepts and relations, the knowledge map defines the common domain knowledge, and the domain specific knowledge includes expert knowledge, engineering function and data analysis based knowledge. Those studies address semantics in the area of product knowledge management. However they didn't properly consider the aspect of semantic interoperability of data. Semantic analysis of data should be added to those studies.

Ko et al [9] developed naming principles for bibliographic information based on ISO/IEC 11179. In this study a semantic data model required for construction of machining databases is developed by combining conventional data models with ISO/IEC 11179. The model can be applied to factual data such

as machining data, which has different characteristics from bibliographic information.

3. Semantic heterogeneities of data

Same data elements in different databases may be differently named and represented due to the preferences of individual developers of the databases. In that case data exchange between databases is impossible without human intervention. This kind of semantic heterogeneities of data are too many in the world.

There are a lot of causes which lead to such an inconsistencies of data [10]. The causes can be divided into two categories: inconsistencies of data elements and value representations

Inconsistency of data elements is mainly caused by different naming. Same concept of a data element can be named similar but not exactly same words by different developers. To avoid the meaning conflict between the data elements differently named analysing the relationships of the words made up of data elements is prerequisite. The most typical reason causing semantic conflicts between data element names is using the relationships such as synonyms, upper terms, lower terms and preferred terms. Other causes are using acronyms, different ordering of words, and typing errors.

Inconsistency of value representations is basically due to the difference between value domains adopted by respective databases. Differences of unit and notational system of value are common causes as well. Value mapping or unit conversion can be used to solve the problems.

The best way to solve these inconsistencies is using same terms which are registered in a common repository of metadata when designing a database.

4. Semantic data model

4.1. Structure of a data element

According to ISO/IEC 11179, a data element consists of an object class(es), a property and a representation. In the conventional data models the part including the property and the representation is called as an attribute as shown in Fig. 1. For example in the data element *country name code*, *country* is an object class, *name* is a property and *code* is a representation. In the conventional data models *name code* is called an attribute. So a data element is simply

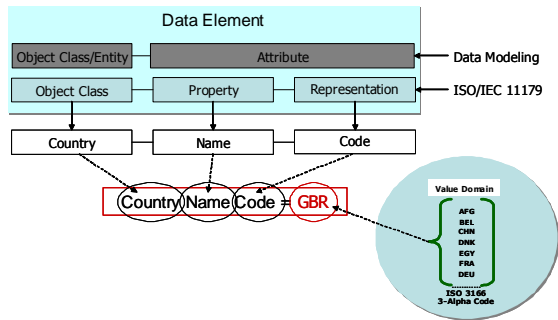


Fig. 1. Structure of a data element

obtained by identifying object classes from an object diagram and then giving attributes to each object. However using attributes without identifying properties and representations is the main cause causing semantic conflicts between databases. Different naming or vague definition of value representation makes computers handle same data differently. In this paper we proposed a methodology in which the attribute is separated into a property and a representation so as to achieve semantic interoperability of data.

4.2. Naming framework of data elements

The part 5 of ISO/IEC 11179 suggests syntax of naming data elements. It recommends database developers to name a data element in the order of object classes (O), a property (P) and a representation (R) successively as shown in Fig. 2 when naming. First of all the object class names are obtained from the object diagram of a data model. Secondly the property name is designated in the process of giving attributes to objects. Finally the representation name is determined according to the type of the value domain corresponding to the data element. In this case standard taxonomies of object classes, properties and representations are required in

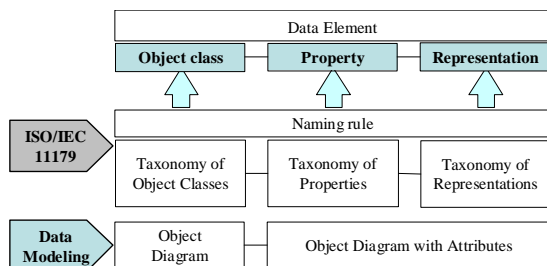


Fig. 2. Naming framework of a data element

order to be referred by the database designers.

4.3. Specification of metadata

After naming data elements metadata should be specified. Common and specific attributes of metadata are to be specified. Common attributes for all kinds of metadata are classified into four categories: identification, definitional, managerial and relational. Attributes specific to each metadata are differently given according to the characteristics of the metadata (See Table 2). Well and consistently specified specifications of metadata are good basis for semantic interoperability of data as well.

5. Application to EDM

The data modelling methodology developed above were applied to the modelling of EDM machining knowledge base, which has simpler data structure than other types of machining. In general machining conditions are determined for given machining requirements by decision-making through analysis and computation required. In the middle of the process machining database should be referred to. And then NC coding is to be performed so as to be exploited in a CNC machine tool.

5.1. Outline of EDM

Electrical Discharge Machining (EDM) is the process of machining electrically conductive materials by using precisely controlled sparks that occur between an electrode (cutting tool) and workpiece in the presence of a dielectric fluid. Diesinking (ram) type

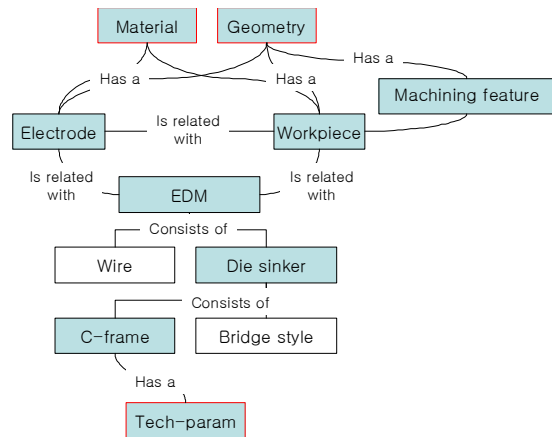


Fig. 3. Object diagram of EDM

Table 1
Properties and representations associated with basic object classes of EDM

Objects	Properties	Representations
Material	Name	code
	Density	g/cc
	Tensile yield strength	MPa
	Compressive yield strength	MPa
	Poisons ratio	ratio
	Modulus of elasticity	GPa
	Hardness	Brinell
	Fatigue strength	MPa
	Shear modulus	GPa
	Electrical resistivity	Ohm-cm
	Heat capacity	J/g-C
	Thermal conductivity	W/m-K
	Melting point	C
Geometry	Point-centre	C-point
	Point-radius	C-point
	Point-height	C-point
	Point-edge-001	C-point
	Point-edge-002	C-point
:	:	
Technical parameter	Intensity	number
	Ionization voltage	V
	Pulse on time	sec
	Pulse off time	sec
	Servo voltage	V
	Return time	sec
	Work time	sec
	Wear value	number
	Removal rate	rate
	Rough gap	mm
	Pressing finishing gap	mm
	Aspiration finishing gap	mm
	Gap with orbital	mm

EDM machine and the Wirecut EDM machine are the most typical. The electrode does not make physical contact with the workpiece for material removal. So EDM has little tool force. EDM is a thermal process.

Between the electrode and the workpiece is

sparkling gap which is the distance required for sparking. Sparking gap will be in an approximate range from 0.0010 to 0.0040 inches. Sparking occurs in a frequency range from 2,000 to 500,000 sparks per second causing it to appear that many sparks are occurring simultaneously.

The sparks occur in a dielectric fluid; hydrocarbon for the Diesinker type EDM machine, and deionised water for the Wirecut EDM machine. The dielectric fluid is an insulator until enough electrical voltage is applied to cause it to change into an electrical conductor. Functions of dielectric fluid in EDM are controlling the sparking gap spacing between the electrode and the workpiece; cooling the heated material to form the EDM chips; and removing EDM chips from sparking area [10].

5.2. Naming data elements

As mentioned 4.2 object class names are identified from the object diagram. Fig. 3 shows the object diagram of EDM. The basic object class of EDM are identified as electrodes, workpieces, machining features and EDM machine. The electrodes and the workpieces include materials and geometries in common as subobjects. The workpieces have machining features, as subobject, which also have geometries as subobject. Meanwhile the EDM machine has technical parameters as subobject. Resultantly EDM has only three basic object classes to be described; *materials, geometries and technical parameters*.

Table 1 shows properties and representations associated with those three object classes. The properties of the materials were obtained from MatWeb [12] while technical parameters were identified by an EDM expert. The properties of the geometries were from a kind of geometrical point expressions in the Cartesian space.

The representations of the properties represent the data types of the value domains, e.g. the unit or the property of each value domain was used as the name of the representation.

Finally all the names of data elements are determined according to the data element naming convention of ISO/IEC 11179. Each data element name consists of three parts (O_P_R) separated by the delimiters (_). Below are some data element names of the electrode and EDM.

- *Electrode-geometry_point-center_C-point*

- *Electrode-geometry_point-radius_C-point*
- *Electrode-geometry_point-height_C-point*
- *EDM-die-sinker-Cframe-technical-parameter_intensity_number*
- *EDM-die-sinker-Cframe-technical-parameter_intensity_number*
- *EDM-die-sinker-Cframe-technical-parameter_ionization-voltage_V*
- *EDM-die-sinker-Cframe-technical-parameter_pulse-on-time_sec*

5.3. Specifying metadata

Table 2 is an example of data element specification performed based on ISO/IEC 11179. Other data elements should be specified in the same form.

5.4. Metadata registry for EDM

Data element specifications should be registered to a central metadata registry so that all persons related to EDM could refer to it. The data element specifications should be qualified through a standardizing process before registration. The process includes modification and retirement processes as well. Fig. 4 shows the process to utilize the EDM metadata registry in order to achieve semantic interoperability between machining requirement and condition databases; 1) First of all a machining database is

Table 2

An example of data element specification

Type	Attribute name	Value
Common	Name	Workpiece-material_name_code
	Context name	EDM
	Context id.	03
	Item id.	001
	Version	100
	Definition	Name code of a workpiece's material
	Definition Lang.	EN
	Registration status	Standard
	Responsible org.	KISTI
	Submitting org.	MEC, Cardiff Univ.
Specific	Value domain name	Material code
	Value domain id.	MCOD
	Datatype name	String
	Datatype scheme ref.	SHOE 1.0
	Representation layout	List
	Representation class	Code
Max. size	100	
Min. size	1	

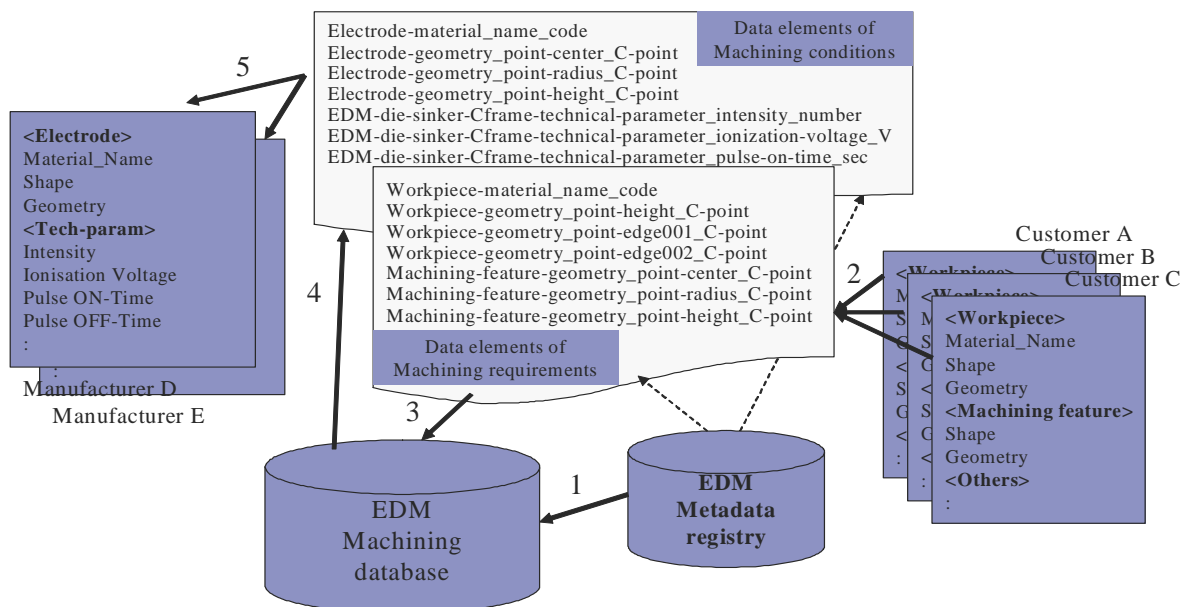


Fig. 4. Conceptual Diagram of using EDM metadata registry

constructed based on the EDM metadata registry. 2) According to the data element names registered in the EDM metadata registry, 3) customers A, B and C access and input machining requirements to the EDM database. 4) Then the EDM database gives to manufacturers D and E machining conditions according to the data element names registered in the EDM metadata registry as well. 5) Finally the different manufacturers can perform the same machining even with different EDM machines.

A web accessible industry metadata registry (IMR) has been developed using ORACLE DBMS with Java JSP on LINUX system [13]. The EDM metadata can be constructed in the IMR using extension function provided.

6. Conclusion and future work

In this paper a semantic data modelling methodology was developed using ISO/IEC 11179 combined with conventional data models. In the methodology a basis of semantic interoperability of data was achieved through naming convention and specification provided by ISO/IEC 11179.

An experimental data model for EDM was implemented by the methodology to show how to achieve semantic interoperability using EDM metadata registry.

The semantic data modelling methodology developed in this paper could be applied to other factual database as well as machining databases. Thus it contributes to avoid semantic inconsistencies existing between databases distributed.

Applications to real problems are desirable and an experiment of semantic data exchange between machines should be performed in a separate study.

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